4.4 Standards, Codes, and Design Guides

4.4.1 Summary of Available Codes and Standards

4.4.1.1 Codes and Standards for Pipelines

Currently used codes and standards for the design of pipelines are listed below:

- Code of Federal Regulations, 49 CFR, Transportation:

  Part 190, "Pipeline Safety Program Procedures"
  Part 191, "Transportation of Natural and Other Gas by Pipeline"
  Part 192, "Transportation of Natural and Other Gas by Pipeline, Minimum Federal Safety Standard"
  Part 195, "Transportation of Hazardous Liquids by Pipeline".

- ASME (ANSI) B31.4, "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols".

- ASME (ANSI) B31.8, "Gas Transmission and Distribution Piping Systems".

- ASME Guide for Gas Transmission and Distribution Piping Systems-1983 (ASME, 1983b). (Recommended practices of ASME Gas Piping Technology Committee)

- API Standard 1104, "Welding of Pipelines and Related Facilities".

- California Public Utility Commission (CPUC), General Order 112-D Rules Covering Design, Construction, Testing, Maintenance and Operations of Utility Gas Gathering, Transmission, and Distribution Piping Systems; Liquid Natural Gas Facilities Safety Standard.

- NAVFAC DM - 22, Petroleum Fuel Facilities

- Department of the Army, CEGS-02685, Guide Specification for Military Construction, Gas Distribution Systems.

- Army TM 5-809-10-1, Navy NAVFAC P-355.1, Air Force, AFM 88-3, Chap. 13, Sec.A, Seismic Design Guidelines for Essential Buildings, pg. 7-2, ¶ 7-7, "Buried Structures".

4.4.1.2 Seismic Design Provisions in the Codes and Standards for Pipelines

Federal regulations for natural gas pipelines do not contain explicit requirements for seismic design. Implicit requirements could be read into Subpart C Section 192.103 of Part 192 of 49 CFR, "General", which requires pipes to withstand "anticipated external pressures and loads that will be imposed on the pipe after installation". No mention is made of compliance

with anticipated ground strains and deformations. Section 840.1 "General Provisions" of ASME Standard B31.8 mentions "unstable ground" and "earthquake induced stresses" as "conditions that may cause additional stress to the line and its appurtenances and shall be provided for". This is an explicit requirement for consideration of seismic loads where they exist, but not for avoidance of hazardous sites. Again no mention is made of compliance with anticipated ground strains and deformations.

The Federal regulation for transportation of hazardous liquids, Part 195 of 49 CFR, does have an explicit requirement for earthquake resistant design of pipelines in ¶ 195.110, "External Loads", which mentions earthquakes. Again, there is no requirement for compliance with ground strains and displacements. Similarly, ASME Standard B31.4 in Section 401.5.3 requires consideration of the dynamic effect of earthquakes in the design of piping systems in regions where earthquakes are known to occur.

NAVFAC DM 22 for petroleum fuel facilities references ASME Standard B31.4, and CEGS Specification 02685 references ASME Standard B31.8. Otherwise, these specifications do not have an explicit requirement for seismic design. The Seismic Design Guidelines of the Armed Services (TM 5-809-10-1, etc.) mention buried structures, but do not recommend seismic displacements or forces for pipelines.

In summary, consideration of earthquake forces is explicitly required in the federal regulations for liquid fuel pipelines, but it is not explicitly required in the federal regulations for natural gas pipelines. The ASME standards require consideration of earthquake forces for all pipelines. These standards apply by reference to military construction.

It could be argued that the ASME requirements, when interpreted by engineers who are familiar with the earthquake problem, could produce adequate designs. However, the lack of specificity in the provisions, as well as the failure to mention the need for siting studies, raises serious questions about the adequacy of current seismic design provisions.

Quality control of welds is a key factor in the construction of earthquake-resistant pipelines. Current U.S. Government regulations for welding of gas and liquid fuel steel pipelines are given in 49 CFR Part 192 and Part 195. Both Parts 192 and 195 make reference to API 1104, which is frequently used in the gas and liquid fuel industries to establish procedures for weld quality and welder qualifications. The welds described are continuous circumferential welds at straight butt-end connections made by means of electric arc procedures. API Standard 1104 also presents methods for the production of high-quality radiographs through the use of qualified technicians and approved methods and equipment, to ensure the proper analysis of the welding quality. This standard is intended to apply to the welding of piping used in the compression, pumping, and transmission of crude petroleum, petroleum products and fuel gases, and to distribution systems when applicable. Details on welding specifications, standards of acceptability, and radiographic procedures are included in the standard.

4.4.1.3 Codes and Standards for Storage Tanks

Currently used codes and standards for the design of storage tanks are listed below:

- Code of Federal Regulations, 49 CFR, Transportation: Part 193, "Liquefied Natural Gas Facilities; Federal Safety Standards"
- API Standard 650, "Welded Steel Tanks for Oil Storage"
- ANSI/AWWA D100, "Standard for Welded Steel Tanks for Water Storage"
- NFPA 59 A, "Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)".
- California Public Utility Commission (CPUC), General Order 112-D,Rules Covering Design, Construction, Testing, Maintenance and Operations of Utility Gas Gathering, Transmission, and Distribution Piping Systems; Liquid Natural Gas Facilities Safety Standard.
- NAVFAC DM - 22, Petroleum Fuel Facilities
- Army TM 5-809-10-1, Navy NAVFAC P-355.1, Air Force, AFM 88-3, Chap. 13, Sec.A, "Seismic Design Guidelines for Essential Buildings", pg. 7-2, ¶ 7-7, "Buried Structures".

4.4.1.4 Seismic Design Provisions in the Codes and Standards for Storage Tanks

API Standard 650 has detailed seismic design requirements in Appendix E. Similar requirements are incorporated in Section 13 of ANSI/AWWA D100.

Part 193 of 49 CFR specifies site investigation and siting requirements for LNG facilities, which include determination of earthquake forces and earthquake induced displacements in Section 193.2061, "Seismic Investigation and Design Forces". Requirements for subsurface investigation are specified in Section 193.2065, "Soil Characteristics". Site investigations are generally performed in accordance with the recommendations in NBSIR 84-2833 (Kovacs et al., 1984). Another provision of this latter standard, which reduces seismic hazards, is a secondary impoundment dike requirement, provided in Sections 193.2149 through 2165. Similar provisions are included in NFPR 59 A.

Part 195 of 49 CFR requires compliance with API Standard 650 by reference in Appendix A.

The armed forces seismic guidelines (Army TM 5-809-10-1) has provisions for ground-based vertical tanks on page 7-2 and for elevated tanks on page 7-1. These provisions are explicit, but more concise than the ASME provisions. Page 7-2 of the document also addresses buried structures, and could be applied to buried tanks. It recommends seismic design for large-diameter buried structures, but not for pipelines.

It is noted that the API and ANSI/AWWA standards, as well as the armed forces standards, while spelling out detailed seismic design requirements, do not address the siting and secondary impoundment problems. While the Federal provisions, which are intended for LNG storage tanks, may be too restrictive for other liquid fuel and gas storage tanks, siting and secondary storage requirements seem also appropriate for these latter facilities.

4.4.1.5 Codes and Standards for Structures and Support Facilities

The most frequently used codes and standards are listed as follows:

- BSSC, "NEHRP Recommended Provisions"
- ICBO, "Uniform Building Code"
- Southern Building Code Congress Int., "Standard Building Code"
- BOCA, "National Building Code"
- SEAOC, "Recommended Lateral Force Requirements"
- NAVFAC DM - 22, "Petroleum Fuel Facilities"
- Army TM 5-809-10-1, Navy NAVFAC P-355.1, Air Force, AFM 88-3, Chap. 13, Sec.A, "Seismic Design Guidelines for Essential Buildings", pg. 7-2, ¶ 7-7, "Buried Structures".
- ASCE Technical Council on Lifeline Earthquake Engineering, "Advisory Notes on Lifeline Earthquake Engineering".
- ANSI/IEEE Standard 344-1987, "Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Stations".
- ANSI\IEEE Standard 693-1984, "IEEE Recommended Practices for Seismic Design of Substations".

4.4.1.6 Seismic Design Provisions in the Codes and Standards for Structures and Support Facilities

Seismic design provisions for structures are incorporated in most building codes in seismic areas and in the model codes listed above. Except for hazardous sites, such as sites in the vicinity of faults and in areas subjected to landslides, liquefaction, and tsunamis, these provisions will generally promote adequate earthquake resistance. Army Manual TM 5-809-10-1 also has adequate provisions for earthquake resistant construction.

Nevertheless, supplemental provisions for the seismic qualification of essential mechanical, electrical, and control equipment components, as well as tiedown requirements for these components should receive consideration. Conservative provisions of this nature were

developed for nuclear power plants (ANSI/IEEE 344-1987), and less conservative provisions also were developed for the design of electrical substations (ANSI/IEEE 693-1984).

4.4.2 Comments on Available Codes and Standards

4.4.2.1 Siting

Siting studies for upgrading earthquake-resistant construction practices need to be considered from a perspective of practicality and cost. Gas and liquid fuel transmission lines are large, high-pressure structures, and it is sensible and economically justifiable to scrutinize their vulnerability to natural hazards which can affect their integrity. Seismological studies should be required to locate causative faults, identify design level and maximum credible earthquakes, and provide appropriate attenuation relationships for the estimation of strong ground motion. Geotechnical studies should focus on identifying active faults, areas of potential liquefaction, potential landslide zones, and areas of exceptionally severe site amplification. The potential ground deformations caused by liquefaction, particularly those associated with lateral spreading, should be estimated. Special attention should be focused on river crossings. Consideration should be given to siting and construction techniques (such as directional drilling) to minimize exposure to liquefaction-induced ground failure at river crossings.

In contrast to siting of transmission pipeline systems, siting studies are generally not needed for distribution piping. The vast number of distribution mains and their restriction to street and highway rights-of-way make the concept of siting studies impractical for each pipeline in this type of system. However, special measures, such as ductile piping and welded connections, could be required for new distribution pipes installed in potentially unstable areas which have been mapped. These areas would include fault zones, which in California have been mapped as Alquist-Priolo Special Study Zones, and zones of ground failure hazards which currently are being mapped on a state-wide basis in California. The Seismic Hazards Mapping Act of 1990 enacted by the State of California calls on the State Geologist to undertake a statewide seismic hazard mapping and technical advisory program, in order to assist cities and counties in fulfilling their responsibilities for protecting the public health and safety against the effects of strong ground shaking and other seismic hazards (Tobin, 1991).

Comments in the technical literature:

> *Many gas and liquid fuel lifeline (GLFL) facilities are sited near the coast; thus, marine as well as terrestrial seismic hazards must be considered in the design. The terrestrial seismic hazards that can affect GLFL facilities are: (1) ground failures which include faulting, landslides, liquefaction, densification, and ground cracks; (2) tectonic uplift and subsidence; and (3) vibratory ground motion. Seismic hazards originating in marine environment that affect coastal GLFL facilities include tsunamis and seiches (ASCE, 1983).*
>
> *Siting criteria for nuclear power plants are quite detailed and are governed by regulatory criteria and requirements In general there are no acceptable methods or approaches that are common to the siting of critical facilities that include pipelines, terminals, major transmission facilities, or substations within urban areas (Hall, 1987).*

4.4.2.2 Pipelines

Comments on available codes and standards in the technical literature:

All of the gas transmission systems in the area of the 1971 San Fernando earthquake which were constructed in accordance with the requirements of General Order 112-D of CPUC and ASME B 31.8 as design criteria, proved to be earthquake resistant (McNorgan, 1973). Contrary to the reported adequacy of current (1971) structural codes for gas transmission pipelines (McNorgan, 1973), Eguchi, 1984, reported that the behavior of lifelines in the 1971 San Fernando earthquake showed up some glaring hazards and demonstrated the need for new design approaches and requirements for lifeline systems.

The Code of Federal Regulations (49 CFR - 1990), Title 49, Parts 192 and 195 provides minimum safety standards for gas and liquid fuel pipelines in the United States. Nyman, 1987, states that many gas and oil pipeline companies exceed CFR requirements for safety, and they have established operating procedures to handle all types of general emergency situations. The companies consider emergencies resulting from earthquakes not altogether different from those resulting from improper excavation, floods, or fires except that the emergencies may occur simultaneously following an earthquake.

The liquid fuel industry has been using ANSI/ASME B 34.1 for the construction of cross country lines. The gas line companies use a somewhat similar standard, ANSI/ASME B 31.8. Both of these standards have been used by all pipeline industries since the 1950 s. The standards have been reviewed and updated by code committees consisting of industry and non industry members (Bagwell and Marshall, 1973).

Procedures for rational and positive corrosion control have been developed and can be economically applied to underground pipelines. The oil and gas industries, and other major users of underground facilities are developing and using underground corrosion control procedures (Kinsey, 1973).

The current state-of-the-art of computational procedures for pipeline loading and performance under earthquake conditions can not be assimilated into the industry until appropriate design criteria and guidelines are established for the information that these procedures produce (Row, 1987). For the past 10 years, designers who have designed earthquake fault crossings have used strain based design criteria. However, the governing U.S. codes of practice (CFR 192 and 195; ASME/ANSI B 31.4 and B 31.8) do not address such criteria. Foreign codes of practice such as DNV, Rules for Submarine Pipelines, Norway, and the draft Canadian pipeline code (CSA Z 187), recommend the use of inelastic analysis methods and strain-based criteria under special circumstances. Row, 1987, concludes that effort must be directed at including the results of research and current state-of-the-art practice into U.S. codes of practice.

The design factors and stress limits in the ANSI/ASME B 31.4 and B 31.8 codes ensure that certain minimum strength resistances are not exceeded by the effects of specified operational loadings. The code provisions are normally adequate for general stress design of conventional pipelines and piping systems (Price and Barnette, 1987). Conventional systems are considered to be onshore pipelines in stable ground. When it is necessary to evaluate structural discontinuities and dynamic fatigue effects, however, the designer is responsible for determining supplemental local stress design specifications. The alternate rules in ANSI/ASME BPV-VIII (ASME Boiler and Pressure Code) are useful for reference purposes and for guidance in evaluating discontinuity, peak stress fatigue, and plastic cycling fatigue from cyclic loads which are not explicitly accounted for in the ANSI/ASME B 31.4 and B 31.8 standards.

The Public Utilities Commission of the State of California issued the following general order in June 1979, "General Order No. 112-D, Rules Governing Design, Construction, Testing, Maintenance, and Operation of Utility Gas Gathering, Transmission, and Distribution Piping Systems, Liquified Natural Gas Facilities Safety Standards". According to Anderson and Bachman, 1985,the resulting design requirements from the General Order are several times greater than the most demanding building code provisions and are generally more conservative than those specified for nuclear power plants in highly seismic regions. The General Order contains the provisions of: The Uniform Building Code; "Tentative Provisions for the Development of Seismic Regulations for Buildings", ATC 3-06, Applied Technology Council, U.S. Government Printing Office, Wash, D.C., June 1978;API 650, "Welded Steel Tank for Oil Storage", API 650, 6th.ed., Revision 3, Appendix E, Seismic Design of Storage Tanks, American Petroleum Institute, Wash, DC, Oct. 1979; "Final Safety Analysis Report San Onofre Nuclear Generating Station Units 2 and 3," Southern California Edison Company and San Diego Gas and Electric Company, June 1979.

It is noted that current design practice does not include a method for calculating the stress induced in a pipe due to longitudinal bending, nor does current practice address the potential fatigue of longitudinal and girth welds (O'Rourke et al. 1987).

4.4.2.3 Storage Tanks

Comments on available codes and standards in the technical literature:

Nyman and Kennedy, 1987 note that design standards such as API 650 and AWWA D100 provide a generally adequate approach to the design of liquid storage tanks. Nearly all liquid storage tanks are quite flexible and unanchored. Improved methods that require an estimate of the tank's natural frequency and a design spectral acceleration are available. The choice of an appropriate approach will generally depend upon the allowable stresses outlined in the design criteria and the risks associated with tank damage (Nyman and Kennedy, 1987).

4.4.2.4 Structures and Facilities

Comments on available codes and standards in the technical literature:

Equipment that is vital for maintaining proper pipeline control and initiating emergency actions must remain operational after an earthquake. Nyman and Kennedy, 1987, reported that presently there are no guidelines that apply for the seismic qualification of equipment for oil and gas lifeline systems.

There are also standards for seismic qualification of equipment used in pipeline facilities. One applicable guideline standard is IEEE 1975, Standard 344, Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations (Anderson, 1985). An important part of any seismic qualification programs is to procure equipment of good quality construction and perhaps heavier gauge material than usual, as this could eliminate problems during qualification (Price and Barnette, 1987).

Conventional structures in seismic zones similar to California are designed to current seismic standards according to the Uniform Building Code (UBC) for the appropriate seismic zone. The UBC procedures for the analysis and design are applicable for above ground structures included in pipeline systems (Nymann and Kennedy, 1987).

4.5 Summary

The greatest earthquake-related threat to pipeline fuel transportation systems is from special site hazards such as fault-displacements, liquefaction, landslides, and tsunamis. By judicious siting, this threat can be minimized, but not entirely avoided for pipelines, and can be for the most part avoided for storage facilities, structures and support facilities. Our present state of knowledge in seismology, geology, and geotechnical engineering enables us to plan and design systems in a manner which will minimize exposure to special site hazards, but with the exception of regulations for LNG facilities, siting requirements are not included in present standards and regulations for pipeline transportation systems.

Standards for pipelines include Federal regulations, ASME recommendations, military standards and State of California standards. With the exception of the State of California standards, none of the standards for pipelines address siting requirements. The federal regulations for liquid fuel pipelines, and the ASME standards, which are also adopted by reference in the military standards, contain a requirement for resisting earthquake forces, but do not mention displacements.

Standards for storage tanks include federal regulations for LNG facilities, API and AWWA standards, military standards and State of California regulations. The Federal regulations and the State of California regulations for LNG facilities address siting and secondary storage. These issues are not addressed in any of the other standards. However, the API and military standards have seismic design provisions, addressing lateral forces. Some authors noted that these provisions should be improved.

Standards for structures and support facilities can be derived for the most part from local building codes, model codes, military specifications, and other documents dealing with the design of earthquake-resistant structures. However, there are no standards specifically dealing with the seismic qualification of equipment components, specifically addressed to pipeline transportation systems, and there is probably a need for special provisions for the tiedown of equipment.

5. FEDERALLY CONTROLLED SYSTEMS

5.1 Introduction

Pertinent Federal Agencies were contacted to obtain the following information:

- Oil and gas pipelines operated, leased or regulated by the Agency.
- Requirements for earthquake resistant design and construction for pipelines under the Agency jurisdiction.
- Plans for retrofit of pipelines which are inadequately protected against seismic hazards.

This section contains concise summaries of the information obtained from telephone conversations with persons from the Agencies contacted. Summaries of telephone conversations with the persons contacted from each Agency are given in Appendix A.

5.2. Federal Practices

DEPARTMENT OF TRANSPORTATION (DOT)

The DOT regulates pipelines through CFR Title 49 Parts 191 to 193, and 195 for natural and other gas and hazardous liquids respectively. These regulations provide minimum safety standards for the United States and they apply to national pipeline systems owned and operated by pipeline operators. Federally owned pipeline systems are exempt from DOT regulations.

The DOT regulations for pipelines address some natural hazards but do not contain explicit seismic design requirements. State utility commissions generally regulate the distribution piping systems by certifying with DOT to administer that program.

DOT follows general rule making procedures in the preparation and issuing of regulations. Petitions for rule making and notices are sent out so that interested persons and organizations can respond and participate. In addition to its regulatory responsibility, the DOT owns a few pipelines and is responsible for their operation. For example, DOT owns a pipeline system at the St. Lawrence Seaway. With this particular pipeline systems there have been no problems caused by seismic events. However, there have been some leaks. There has been some retrofitting and replacement of pipe due to corrosion. Emergency procedures provide for pipeline shut down.

As an example, DOT recently reviewed a liquid fuel transmission pipeline design for a section of pipeline near San Bernardino, CA that replaced a section of pipeline that was damaged by a derailed train. The regulations used in the design were 49 CFR Part 195 and included seismic provisions including an equation for adding hoop stress and outside stress in accordance with ANSI/ASME B 31.4 and B 31.8. With regard to seismic provisions for the Trans-Alaskan pipeline, sections that cross known faults are above ground. DOT personnel believe that geological studies are performed in many areas to avoid seismic risk, especially on the West Coast. However, in the Northeastern part of the United States seismic design provisions are not usually considered.

Both DOT and the Department of Interior's Minerals Management Service regulate pipeline operators offshore facilities. About 75 percent of these facilities are regulated by DOT and the others are regulated by the Department of Interior.

DEPARTMENT OF ENERGY (DOE)

With the exception of the Federal Energy Regulatory Commission, DOE does not own, operate, lease, or regulate oil, fuel, or gas transmission pipeline systems. They do own, and are responsible for the operation of, lines on their sites.

As an example, DOE is responsible for petroleum reserves stored in California and Wyoming. The Naval Petroleum Reserve became a part of DOE in 1975. In the petroleum reserves, oil is pumped from ships to underground caverns which may involve commercial pipelines. At some petroleum reserve sites, DOE utilizes an operating contractor who also does the engineering work. Each DOE site has to prepare a site development plan.

There have not been any reported earthquake related problems with pipeline systems. However, because of corrosion and modernization of existing lines, there has been some retrofit and replacement of existing pipeline systems. Some post World War II pipeline systems have been replaced with modern equipment. Performance is periodically checked by helicopter overflights over the pipeline system and by monitoring pipelines for corrosion.

The most up-to-date codes and standards are used in the design and construction of pipeline systems. DOE does not have its own set of design guidelines. Contractors must follow DOE orders which include UBC by reference (zone 4). DOE Order 6430.1A (1988) presents design criteria for new facilities and includes safety classes. Also used by DOE is UCRL-15910, "Design And Evaluation Guidelines For DOE Facilities Subject To Natural Phenomenon Hazards". This guideline includes seismic provisions. DOE also has guidelines for nuclear power plants (NE F9-2T). API requirements are followed for pipelines and tanks along with Navy requirements for these systems and also for retrofit and replacement. DOE does not have a retrofit policy. Retrofit is performed on a case by case basis, but is not generally applicable to pipelines. A seismic analysis is always addressed in the design of pipeline systems. These systems, which include all the necessary components, are designed by contractors selected by DOE. Guidelines are needed by DOE for seismic provisions for the design of pipeline systems.

The DOE Office of Energy Emergency Operations has looked into the possible effect of a major earthquake on pipelines in the New Madrid fault area. This effort has been coordinated with those of the Center for Strategic International Studies. The principal concerns are with mitigation, response, and recovery of pipelines subjected to a major earthquake in the New Madrid fault area. Issues to be considered are design criteria, recommendations for operations, needed research, and financial estimates regarding mitigation, response, and recovery. As an example, redundant pipeline systems may be considered as a possible solution to avoid a catastrophe.

FEDERAL ENERGY REGULATORY COMMISSION (FERC)

The FERC was established under DOE by Title 18, CFR, "Conservation of Power and Water Resources", Chapter I. Gas pipelines and LNG facilities are subject to FERC review. Seismic provisions fall under the environmental protection requirements of 18 CFR.

With respect to gas pipelines, FERC reviews proposed designs for potential earthquake hazards where pipelines cross streams, rivers, or geological faults.

For LNG facilities, FERC conducts project-specific reviews of proposed engineering designs using engineering judgments. The designs must comply with 49 CFR Part 193. More specific guidelines for site investigation are spelled out in Section 380.12 (6) and (7) of 18 CFR. NBSIR 84-2833 (Kovacs, 1984) which has been prepared for FERC contains guidelines for site investigations.

FERC seismic and geologic reviews include geologic descriptions of the project area and detailed consideration of adjacent faults, potential for landslides and liquefaction, and area seismicity.

DEPARTMENT OF INTERIOR (DOI)

Under the Outer Continental Shelf (OCS) Lands ACT (43 U.S.C. 1334), the Minerals Management Service (MMS) in the Department of the Interior (DOI) issues leases for the exploration and development of oil and gas and other minerals in the OCS. The MMS issues pipelines rights-of-way on the OCS for the transportation of oil, natural gas, sulphur, or other minerals, under such regulations and conditions as may be prescribed by the Secretary of the Interior (or, where appropriate, the Secretary of Transportation). Regulatory responsibilities of MMS focus on prevention of waste, protection of the environment, conservation of natural resources, production measurement, and safety of OCS lessee and right- of-way holder activities.

There are about 18,000 miles of offshore oil and natural gas transmission pipelines that are jointly regulated by the DOI and the DOT under a 1976 Memorandum of Understanding (MOU) on offshore pipelines. Of the total, 4,500 miles, primarily gathering lines associated with oil and gas production facilities, are regulated solely by MMS. The MMS jurisdiction over offshore pipelines is in the OCS and ends at the Federal\State jurisdictional boundary, generally 3 miles from shore. The DOT's jurisdiction includes pipelines both in the OCS and in State waters.

Under the terms of the 1976 MOU, there are between 70 and 80 structures (primarily pipeline manifold and compressor platforms) currently under DOT jurisdiction. The MOU is being considered for a possible revision in which the jurisdiction of these structures and pipelines would change.

If the effects of scouring, soft bottoms, or other environmental factors are observed to be detrimentally affecting a pipeline, a plan of corrective action must be submitted for MMS approval and following repairs a report of the remedial action taken must be submitted to the MMS by the lessee or right-of-way holder.
During the past 10 years, pipeline-related spills have accounted for about 95 percent by volume of all oil spilled from OCS operations. Therefore, to further reduce spillage related to OCS production, it is necessary to concentrate more on pipeline operations.

During the period 1964 through 1989, of the total volume spilled from pipelines, about 93 percent was from ship-pipeline interactions, primarily ship anchors being dragged over pipelines. This percentage increased to nearly 97 percent for the period 1981-1989. Ship-pipeline interactions usually result in very large spills that heavily skew spill statistics. For example, one such incident in February 1988 resulted in a spill of 14,944 barrels, or about 70 percent of the volume of all spills of 50 barrels or greater for the period 1981 through 1989.

An analysis of 20 years of pipeline failure data compiled by MMS concluded that most remaining pipeline spillage results from pipeline corrosion. Pipeline failures due to external corrosion is more frequent among small sized lines, whereas failures due to internal corrosion are more frequent among medium and larger size pipelines (Mandke, 1990). As the Gulf of Mexico pipeline infrastructure ages, corrosion problems may occur more frequently.

The **Bureau of Land Management** monitors the pipelines across federal lands to determine if the provisions of the right-of-way grant are met. An example of one of the pipelines monitored by the Department of Interior is the Trans-Alaskan pipeline. Design and construction of pipelines across federal lands must comply with DOT regulations.

DEPARTMENT OF DEFENSE (DOD)

The DOD owns some fuel transmission pipeline systems. As an example, they have a pipeline in Maine that is over 200 miles long. There are branch lines from commercial transmission pipelines that provide delivery service to many military installations. DOD also has internal distribution systems at military installations.

In most instances, the distribution systems for natural gas are commercial systems which are locally owned and operated. Essentially the DOD is a customer in the market place and depends on the commercial sector for fuel. They pay for what they use.

Past earthquakes have not caused problems for DOD pipeline systems. Some leaks have occurred in pipelines, but these were due mainly to accidents (or other unforseen conditions or events) or cathodic action on the pipelines. Some earthquake related problems were reported for commercial transmission pipeline systems such as Southern Pacific and Cal Nev. However, specific problems were not identified.

Requirements developed by the Defense Fuel Supplies Center (DFSC) have been used in the design and construction of pipeline systems. Contractors designing pipelines for DOD follow state and federal codes. There have been studies for DOD regarding seismic needs or requirements for retrofit. Many lines have been replaced because of environmental requirements.

DOD - NAVY

The Navy has fuel and oil storage facilities. These facilities are sometimes operated by contract and include transporting oil from docking areas to fuel tanks and from oil storage to barges. The Navy stores fuel for the Air Force and the Army. The Navy does not own, operate, lease, or regulate any oil, fuel, or natural gas transmission pipeline systems. They do have distribution pipeline systems for liquid fuel and for natural gas.

The Navy is responsible for the operation, maintenance, and construction of their pipeline systems. Some storage facilities date back to 1918 and many others were installed during World War II. Many pipeline systems are old. Some pipelines have been replaced because of corrosion and some have been retrofitted. Retrofit has included some internal lining, additional isolation, and automation provided for leak detection. Retrofit by commercial pipeline companies has involved plastic linings in plastic pipes. Only one type of valve was approved by the Navy that was considered to function satisfactorily. This valve for pipe-tank connections has been used for new construction and for replacement.

Past earthquakes caused no significant problems to oil, fuel, or natural gas pipelines. Some water lines were damaged at Treasure Island, California during the Loma Prieta earthquake. There was no damage to utility systems during this earthquake. Liquefaction has been the

cause of some pipeline problems. Some buildings were damaged during the Alaskan earthquake, and there was damage to non-Navy tanks during the 1971 San Fernando earthquake. Decisions on shutting down pipelines are made by individual bases.

Standards used in the design and construction of pipeline systems include NAVFAC P-355.1, "Seismic Design Guidelines For Essential Buildings"; NAVFAC Design Manual 22, "Petroleum Fuel Facilities"; API 650 for tanks; and CFR Title 49 Parts 192 and 195. Navy designs are according to seismic zone and Navy guide specs are used. Geological studies are carried out along with a seismic analysis for design of Naval facilities. Borings are generally required. The Navy generally requires more isolation capability than given in standards and guidelines. Double ball joints are used for tank connections. The standards and guidelines available and used by

the Navy do not give much guidance with regard to seismic provisions in the design and construction of oil, fuel, and natural gas pipeline systems. The designer is alerted to address seismic provisions in the design of pipeline systems.

DOD - ARMY

The Army has some pipelines that they own and operate. Many of these pipelines are old. The Army also has some fuel storage tanks. There has not been reported damage to Army-owned pipeline systems caused by earthquakes, however, one person interviewed thought that he had heard of some pipeline system damage attributed to earthquakes.

With regard to design criteria for pipeline systems, the Army uses Technical Manual TM 5-809-10-1, "Seismic Design Guidelines For Essential Buildings"; guide specifications for new construction of gas distribution systems and liquid fuel storage systems; and Navy Manual 22,"Petroleum Fuel Facilities". DOT regulations are generally followed, even though facilities on DOD property are exempt from DOT regulations. None of the above listed criteria address seismic provisions for transmission pipeline systems.

There has been some retrofit of pipeline systems, but not for reasons of seismic damage or to provide earthquake resistant design. Tanks and pipelines have been repaired and in some cases pipelines have been replaced. Each base has its own policy regarding retrofit and replacement procedures.

DOD - AIR FORCE

The Air Force owns and operates liquid fuel pipeline systems located on their installations in the United States and in foreign countries. Some of the pipeline systems are old. The Air Force does not own, operate, lease, or regulate oil, fuel, or natural gas transmission pipeline systems.

Design criteria used by the Air Force for pipeline systems include DOT regulations, API requirements, ASME/ANSI requirements, and Army and Navy guide specs and design manuals. Guide specs for the design of bulk storage tanks are being updated. In general, present design criteria do not address seismic provisions for earthquake resistant design for pipeline systems. Design considerations generally include environmental and safety requirements.

There have not been any known problems with Air Force owned or operated pipeline systems caused by earthquakes. Also, there are not any plans for retrofitting these systems based on seismic considerations. There has been some repair of tanks because of leaks.

The recent (November 1990) design of above - ground steel tanks for aircraft fuel storage for the Air Force was based on criteria for seismic zones 1 and 2. The specification stated that if the site specific design criteria exceed the general design criteria, structural elements shall be redesigned if necessary. Seismic investigation and redesign shall be in accordance with API 650 and TM 5-809-10/NAVFAC P-355/AFM 88-3,Chapter 13. The tanks were designed by a contractor by authority of the Corps of Engineers. Navy and Army guide specifications were used in the design of these fuel storage tanks. Specific provisions for seismic design were not given in the specification for the design of these steel tanks.

GENERAL SERVICE ADMINISTRATION (GSA)

GSA is not involved with oil, fuel, or natural gas transmission pipeline systems. On GSA sites, distribution lines are the responsibility of the utility company. GSA is mostly concerned with buildings and with regard to seismic design provisions they have adopted the UBC. GSA is also currently preparing additional seismic criteria for the design of their buildings.

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)

HUD is not involved with oil, fuel, or natural gas transmission pipeline systems, however they have some involvement with distribution pipeline systems, in particular for public housing. HUD generally provides the funds for these distribution systems and approves the design of the systems. Local codes, reference standards, and reference model building codes are used in the design of the distribution pipeline systems.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA does not own, operate, lease, or regulate oil, fuel, or natural gas transmission pipeline systems. They do own and operate gas distribution lines at some facilities such as the Ames Research Center, California. Transmission pipelines are operated by utility companies. From these transmission pipelines, NASA takes oil and gas into the facility for internal use. The internal lines range in age from relatively new to the 1940's. The distribution lines include some pipeline support facilities.

There have been minor problems at the Ames Research Center caused by earthquakes such as broken gas lines and leaks at connections and valves. However, the overall performance of the piping systems has been satisfactory. There was an earthquake in 1989 at the Ames Research Center.

Current design procedures which include national standards are used by NASA in the design and construction of pipeline systems. There has been little retrofit or replacement of pipelines. Retrofit for gas lines at the Ames Research Center has been by the use of plastic linings, and steel pipe has been replaced with plastic pipe. Pacific Gas and Electric Company (PGE) uses plastic gas lines in their distribution systems.

Some emergency procedures included use of backup generators with alternate fuel sources for generation of power and heat, and for short periods a propane backup system is available. Pipelines can be shut down or isolated in some cases by acceleration activated automatic valves and some manually operated valves are in use.

OTHER FEDERAL AGENCIES

The **TENNESSEE VALLEY AUTHORITY** (TVA) is not involved with oil, fuel, or natural gas transmission pipeline systems. They do have some distribution systems. The **DEPARTMENT OF AGRICULTURE** (DOA), the **ENVIRONMENTAL PROTECTION AGENCY** (EPA), and the **FEDERAL HIGHWAY ADMINISTRATION** (FHWA) are not involved with oil, fuel, or natural gas transmission pipeline systems.

6. SUMMARY AND RECOMMENDATIONS

6.1 Summary of Findings

6.1.1 System Vulnerability

The overall performance record of gas and liquid fuel pipeline systems subjected to earthquakes has been good. However, serious failures did occur in several earthquakes, particularly in areas of unstable soils.

Modern welded ductile steel pipelines with adequate corrosion protection have a good performance record. Failures, which have occurred in these types of pipelines, were mostly caused by fault displacements, lateral spreading and settlement due to liquefaction, and other large permanent soil displacements. Older pipelines have been damaged many times, including welded pipelines built generally before 1950 in accordance with quality control standards less stringent than those used currently, and segmented cast iron pipelines. Corrosion was the cause of some of the failures that occurred. Pipeline locations vulnerable to damage are bends, elbows, tees, and local eccentricities, and joints in segmented pipelines. Some pipeline failures were attributable to the collapse of supporting structures to which they were attached, such as bridges.

Above-ground storage tanks, particularly those with large height-to-width ratios, have been damaged in many earthquakes. This is attributed to the fact that unpressurized tanks, though structurally very efficient to support vertical gravity loads, are not structurally efficient to resist lateral earthquake forces. The most frequent failure mode is buckling of the shell (elephant's foot buckling). Some of the failures were caused by inadequate anchorage and excessive foundation settlements. Failures were also caused because of inadequate flexibility of pipe connections and contact of the sloshing liquid with the roof structure.

Pumping stations and compressor stations are not very vulnerable. Other above ground support facilities, which were designed to resist earthquakes, suffered only limited damage, which in many instances was caused by inadequate tiedown of equipment or insufficient anchorage to the supporting foundations. Equipment outages were mostly caused by falling debris, collision with other items, sliding, or failure of electrical supplies.

6.1.2 Remedial Measures

The most efficient and economical way to obtain earthquake protection for new facilities is proper siting. Storage tanks and other above-ground facilities should be kept away from special hazard areas, such as geological faults, liquefiable soil deposits, potentially unstable slopes, areas of deep soft soil deposits, and areas that could be subjected to tsunamis, seiches, and other forms of flooding. Pipelines cannot always be located away from hazardous sites, particularly distribution lines, but their exposure to special site hazards can be minimized.

In addition to proper siting, pipelines and structures can be designed to resist earthquake loads and displacements. Criteria for pipeline design were presented by ASCE (1984), and criteria for tanks and other structures are incorporated in many existing standards.

Protection against the environmental consequences of storage tank failures can be provided by secondary containment using earth dikes. Such secondary containments are presently required for LNG storage facilities but not for oil storage tanks.

Connections with tanks, underground utility structures, and valves deserve special consideration. Such connections should be flexible, allowing for rotation to accommodate differential settlement, and should have adequate horizonal restraint to prevent pullout. Penetrations of building walls and bridge abutments should be oversized, with appropriate waterproof and compressible packing to allow for differential settlement. The integrity and ductility of gas, liquid fuel, and critical water pipelines must be ensured at penetrations.

For existing facilities, retrofit and replacement of older facilities in critical areas should be considered. Methods for inspecting and retrofitting older pipelines are available.

Gas and liquid fuel companies operating in areas vulnerable to earthquakes should prepare a formal and formally approved emergency plan for safety, restoration, and environmental protection. The plan should consider a variety of natural disasters applicable within the company's jurisdiction, including seismic events. The plan should address reciprocal agreements for assistance with neighboring utilities, alternative supplies of electricity and water, communications, monitoring, and practices of emergency operations. It is recognized that it is not possible or practical to design and maintain gas and liquid fuel pipeline systems that will never experience an emergency situation. The Federal regulations help establish procedures to deal with emergencies in an orderly fashion (ASCE, 1984).

6.1.3 Existing Guidelines and Standards

Present standards for pipeline systems generally do not address adequately their protection against earthquake damage. This is attributable to the perception that modern welded pipelines are not vulnerable to earthquakes. Current allusions to seismic loading and ground subsidence conditions in CFR Title 49 Parts 192 and 195, as well as relevant ASME standards, are thin and not sufficiently detailed to give reasonable guidance for line pipe and related facilities. Some improvement in the design standards should be sought. Such improvements might ultimately take the form of explicit and carefully phrased performance specifications with reference to relevant detailed design standards which have been developed in model form by organizations such as TCLEE,NIST and NCEER.

Present standards for above-ground liquid fuel storage tanks contain provisions for lateral force design which are based on the present state of the art.

Neither the pipeline standards nor the standards for oil storage tanks address the need for siting studies, even though such studies are often performed in practice. This deficiency could have adverse consequences, particularly in the Central and Eastern U.S., where the need for earthquake resistant design is not always fully recognized. There are also no secondary containment requirements for liquid fuel storage tanks, even if these tanks are located in environmentally sensitive areas.

Standards for LNG storage facilities contain siting criteria, secondary storage provisions and lateral force design requirements.

6.1.4 Federal Practices

Three Federal Agencies have regulatory responsibilities for pipeline fuel transportation systems: The DOT regulates oil and gas pipelines with respect to safety; FERC regulates the fuel transmission rates charged by oil and gas transmission lines, as well as monitors compliance of gas pipelines and all LNG facilities, including terminal and storage facilities, with safety and environmental requirements; and the MMS regulates compliance of offshore production and transmission facilities with safety and environmental requirements. MMS regulates approximately 25 percent of the offshore transmission pipelines, and DOT regulates the other 75 percent. To some extent, the responsibilities of these agencies overlap.

The review and approval of facilities by these agencies are based on the relevant provisions in the Code of Federal Regulations (CFR) and on engineering judgment. Explicit requirements for geological and seismological studies, secondary storage, and earthquake resistant design are included in the federal regulations for LNG facilities. The federal regulations for gas pipelines, as well as other standards referenced in these regulations, do not address earthquake resistant design. The federal regulations for liquid fuel pipelines have a very general requirement for earthquake resistant design which is not adequate for clear guidance on seismic factors. However, ASME and API standards, which address earthquake resistant design for liquid fuel storage tanks, are adopted by reference. These latter standards do not address the siting and secondary storage problems.

Most federal agencies do not own and operate pipeline systems (except for granting rights of way), however some agencies do own and operate relatively short oil and gas transmission pipelines. Many agencies own distribution systems and storage facilities. Most agencies address the earthquake problem in some way, but there is no uniform approach to the problem between agencies, and sometimes within agencies.

6.2 Recommendations

It is recommended that a guideline be prepared for Federal Agencies for earthquake resistant design of gas and liquid fuel pipeline systems which will promote a uniform approach to earthquake resistant practices by all Federal Agencies. This guideline should adopt existing standards and regulations by reference, but add requirements in the following areas:

- Seismologic, geologic, and geotechnical studies and siting requirements for gas and liquid fuel pipeline systems, including storage and support facilities.

- Secondary storage requirements for above-ground oil storage tanks in environmentally sensitive locations.

It is also recommended that the seismic site exploration provisions for LNG facilities given in NBSIR 84-2833 be reviewed and updated if necessary. This document was prepared in 1984, and it should be coordinated with present seismic zoning concepts.

Since the proposed federal guideline may eventually result in an updating of present federal regulations, close coordination between FEMA, DOT, FERC, and MMS, as well as input from industry, will be required.

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APPENDIX DISCUSSIONS WITH STAFF MEMBERS FROM FEDERAL AGENCIES

DEPARTMENT OF TRANSPORTATION (DOT)

Transportation: **Donald R. Trilling**
Office Of Pipeline Safety: **Cesar Deleon, Bob Holter**
Office of Emergency Transportation: **Pete Sill**

The DOT regulates pipelines through CFR Title 49 Parts 192 and 195 for natural and other gas and hazardous liquids respectively. These regulations provide minimum safety standards for the United States and they apply to national pipeline systems owned and operated by pipeline operators. Federally owned pipeline systems are exempt from DOT regulations.

The DOT regulations address some natural hazards but do not provide specific provisions for earthquake resistant design or seismic design requirements. State utility commissions generally regulate distribution piping systems by certifying with DOT to administer these programs.

DOT follows general rule making procedures in preparing and issuing of regulations. Petitions for rule making and notices are sent out so that interested persons and organizations can respond and participate.

The DOT owns a few pipelines and is responsible for operating them. For example, DOT owns a pipeline system at the St. Lawrence Seaway. There have been no problems with the pipeline systems caused by earthquakes. There have been some leaks and some retrofitting and replacement of pipe due to corrosion. Emergency procedures provide for pipeline shut down.

Bob Holter reviewed a liquid fuel transmission pipeline design for a section of pipeline that was replaced. This section of pipeline, near San Bernardino, CA, was damaged by a derailed train. The regulations used in the design were 49 CFR Part 195 and included seismic provisions including an equation for adding hoop stress and outside stress in accordance with ASME B 31.4 and B 31.8. With regard to seismic provisions for the Trans-Alaskan pipeline, sections that cross known faults are above ground.

Mr.Holter believes that in general geological studies are performed to avoid seismic risk especially on the West Coast. The Northeastern part of the United States is not usually considered for seismic design provisions.

With regard to offshore pipeline facilities, DOT, in conjunction with the Department of Interior's Mineral Management Service, regulates these pipeline operators. About 75 percent of these facilities are regulated by DOT and the others are regulated by the Department of Interior.

DEPARTMENT OF ENERGY (DOE)

DOE : **James R. Hill, Chester Bigelow**
Oak Ridge National Laboratory (ORNL): **Jim Beavers**
Energy Emergency Operations: **Jack Wagner**
Naval Petroleum Reserves: **Mike Ruiz**

DOE does not own, operate, lease, or regulate oil, fuel, or gas transmission pipeline systems. They do own, and are responsible for, the operation of lines on their sites. As an example, DOE is responsible for petroleum reserves stored in California and Wyoming. The Naval Petroleum Reserve became a part of DOE in 1975. With regard to petroleum reserves, oil is pumped from ships to caverns which may involve commercial pipelines. At some petroleum reserve sites, DOE utilizes an operating contractor who also does the engineering work. Each DOE site has to prepare a site development plan.

There have not been any reported problems to pipeline systems caused by earthquakes. However, due to corrosion and modernization, there has been some retrofit and replacement of pipeline systems on site. Some post World War II pipeline systems have been replaced with modern equipment. Routine helicopter flight over the pipeline system and monitoring of pipelines for corrosion are methods for periodic checks on performance.

The most up-to-date codes and standards are used in the design and construction of pipeline systems. DOE does not have its own set of design guidelines. Contractors must follow DOE orders which include UBC (zone 4). DOE Order 6430.1A (1988) contains general design criteria for new facilities and includes safety classes. Also used by DOE is UCRL-15910,"Design And Evaluation Guidelines For DOE Facilities Subject To Natural Phenomenon Hazards". This latter guideline includes seismic provisions. DOE also has guidelines for nuclear power plants (NE F9-2T). API requirements are followed for pipelines and tanks along with Navy requirements for these systems and also for retrofit and replacement. DOE does not have a retrofit policy. Retrofit is performed on a case by case basis, but is not generally applicable to pipelines. A seismic analysis is always used in the design of pipeline systems. These systems which include the necessary components are designed by contractors selected by DOE. Guidelines are needed by DOE for seismic provisions for the design of pipeline systems.

The DOE Office of Energy Emergency Operations has looked into the possible effect of a major earthquake on pipelines in the New Madrid fault area. This effort has been coordinated with those of the Center for Strategic International Studies. The principal concerns are with mitigation, response, and recovery of pipelines subjected to a major earthquake in the New Madrid fault area. Issues to be considered are design criteria, recommendations for operations, needed research, and financial estimates regarding mitigation, response, and recovery. As an example, redundant pipeline systems may be considered as a possible solution to avoid a catastrophe.

FEDERAL ENERGY REGULATORY COMMISSION (FERC)

Bob Arvedlund, Marty Burless, Rich Hoffman,

For oil transmission pipelines, FERC only regulates rates.

For gas pipeline systems, FERC performs the following functions:

- Regulation of rates for gas pipelines
- Authorization to build (environmental issues considered)

Justification of need and intended use of the pipeline is submitted to FERC, and approval must be granted. Requirements for approval, including environmental requirements are given in 18 CFR. The type of data that must be supplied to FERC is also stated in the CFR.

FERC conducts environmental reviews for gas and LNG facilities. For pipelines, the review covers earthquakes to some extent, with particular attention to stream and river crossings (the design is reviewed). With regard to LNG facilities, the design must comply with the DOT requirements in 49 CFR Part 193. More specific guidelines for site investigation are spelled out in Section 380.12 (6) and (7) of 18 CFR. NBSIR 84-2833 (Kovacs, 1984) which has been prepared for FERC contains guidelines for site investigations, and the applicant must supply a report in accordance with the stipulations in NBSIR 84-2833.

FERC reviews are project specific. The review of proposed engineering designs is based on engineering judgment.

DEPARTMENT OF INTERIOR

Bureau of Land Management: **Bob Lawton**
Bureau of Reclamation: **Bob McDonald, David P. Prosser**
Minerals Management Service: **Elmer Danenberger**
USGS: **E.V.Leyendecker, James Devine**
Under the Outer Continental Shelf (OCS) Lands Act (43 U.S.C. 1334), the Minerals Management Service (MMS) in the Department of the Interior (DOI) issues leases for the exploration and development of oil and gas and other minerals in the OCS. The MMS currently regulates about 3,800 oil and gas production platforms and structures on the OCS. This regulation also applies to the pipelines associated with these facilities. The MMS issues pipelines rights-of-way on the OCS for the transportation of oil, natural gas, sulphur, or other minerals, under such regulations and conditions as may be prescribed by the Secretary of the Interior (or, where appropriate, the Secretary of Transportation). Regulatory responsibilities of MMS focus on prevention of waste, protection of the environment, conservation of natural resources, production measurement, and safety of OCS lessee and right-of-way holder activities.

There are about 18,000 miles of offshore oil and natural gas transmission pipelines that are jointly regulated by the DOI and the DOT under a 1976 Memorandum of Understanding (MOU) on offshore pipelines. Of the total, 4,500 miles (primarily gathering lines associated with oil and gas production facilities) are regulated solely by MMS. The MMS jurisdiction over offshore

pipelines is in the OCS and ends at the Federal\State jurisdictional boundary, generally 3 miles from shore. The DOT's jurisdiction includes pipelines both in the OCS and in State waters.

Under the terms of the 1976 MOU, there are between 70 and 80 structures (primarily pipeline manifold and compressor platforms) currently under DOT jurisdiction. The MOU is being considered for a possible revision in which the jurisdiction of these structures and pipelines would change.

If the effects of scouring, soft bottoms, or other environmental factors are observed to be detrimentally affecting a pipeline, a plan of corrective action must be submitted for MMS approval and following repairs a report of the remedial action taken must be submitted to the MMS by the lessee or right-of-way holder.

During the past 10 years, pipeline-related spills have accounted for about 95 percent by volume of oil spilled from OCS operations. Therefore, to further reduce spillage related to OCS production, it is necessary to concentrate more on pipeline operations.

During the period 1964 through 1989, of the total volume spilled from pipelines, about 93 percent was from ship-pipeline interactions, primarily ship anchors being dragged over pipelines. This percentage increased to near 97 percent for the period 1981-1989. Ship-pipeline interactions usually result in very large spills that heavily skew spill statistics. For example, one such incident in February 1988 resulted in a spill of 14,944 barrels, or about 70 percent of the volume of all spills of 50 barrels or greater for the period 1981 through 1989.

An analysis of 20 years of pipeline failure data compiled by MMS concluded that most remaining pipeline spillage results from pipeline corrosion. Pipeline failures due to external corrosion is more frequent among small sized lines, whereas failures due to internal corrosion are more frequent among medium and larger size pipelines (Mandke, 1990). As the Gulf of Mexico pipeline infrastructure ages, corrosion problems may occur more frequently.

The Bureau of Land Management monitors the pipelines across federal lands to determine if the provisions of the right-of-way grant are met. An example of one of the pipelines monitored by the Department of Interior is the Trans-Alaskan pipeline. The design and construction of pipelines crossing federal lands must comply with the DOT regulations.

The USGS is currently working on spectral mapping of peak ground accelerations and response spectra for use in seismic design. The USGS is not currently conducting work pertaining to lifelines.

DEPARTMENT OF DEFENSE (DOD)

Defense Fuel Supply Center (DFSC): **Chet Doberson, Anne Scheulan, Eddie French**
Military Transportation Management Command (MTMC): **David Fuchs**
Defense Logistic Agency (DLA): **Don Neri**

The DOD owns some fuel transmission pipeline systems. As an example, they have a pipeline in Maine that is over 200 miles long. There are branch lines off of commercial transmission

pipelines that provide delivery service to many military installations. DOD also has internal distribution systems at military installations. In general, the distribution systems for natural gas are commercial systems which are locally owned and operated. Essentially the DOD is a customer in the market place and depends on the commercial sector for fuel. They pay for what they use.

Past earthquakes have not been a problem with the DOD pipeline systems. Some leaks have occurred in pipelines, but these were due mainly to accidents (or other unforseen conditions or events) or cathodic action on the pipelines. There were reported problems with some commercial transmission pipeline systems such as Southern Pacific and Cal Nev which were caused by earthquakes. Specific problems were not identified.

Requirements developed by DFSC have been used in the design and construction of pipeline systems. Contractors designing pipelines for DOD follow state and federal codes. There have been studies for DOD regarding seismic needs or requirements for retrofit. Many lines have been replaced because of environmental requirements.

DOD - NAVY

Naval Facilities Command (NAVFAC): **Howard Nickerson, Harry Zimmerman, Richard Thomas**

Naval Civil Engineering Laboratory (NCEL): **Ting Lee Lew, John M. Ferritto, Gary Anguiano**

The Navy has fuel and oil storage facilities. These facilities are sometimes operated by contract and include transporting oil from docking areas to fuel tanks and from oil storage to barges. The Navy stores fuel for the Air Force and the Army. The Navy does not own, operate, lease, or regulate any oil, fuel, or natural gas transmission pipeline systems. They do have distribution pipeline systems for liquid fuel and for natural gas.

The Navy is responsible for the operation, maintenance, and construction of their pipeline systems. Some storage facilities date back to 1918 and many others were installed during World War II. Many pipeline systems are old. Some pipelines have been replaced because of corrosion and some have been retrofitted. Retrofit has included some internal lining, additional isolation, and automation provided for leak detection. Retrofit by commercial pipeline companies has involved plastic linings in plastic pipes.

There has been little or no problems to oil, fuel, or natural gas pipelines caused by earthquakes. Some water lines were damaged at Treasure Island, California during the Loma Prieta earthquake. There was no damage to utility systems during this earthquake. Liquefaction has been the cause of some pipeline problems. Some buildings were damaged during the Alaskan earthquake and there was damage to non-Navy tanks during the 1971 San Fernando earthquake. Policy decisions on the shutting down of pipelines are made by individual bases.

Standards used in the design and construction of pipeline systems include NAVFAC P-355.1,"Seismic Design Guidelines For Essential Buildings"; NAVFAC Design Manual 22,"Petroleum Fuel Facilities"; API 650 for tanks; and CFR Title 49 Parts 192 and 195. Navy designs are according to seismic zone and Navy guide specs are used. Geological studies are

carried out along with a seismic analysis for design of Naval facilities. Borings are generally required. The Navy generally requires more isolation capability than given in standards and guidelines, double ball joints are used for tank connections.

The standards and guidelines available and used by the Navy do not give much guidance with regard to seismic provisions in the design and construction of oil, fuel, and natural gas pipeline systems. The designer is alerted to address seismic provisions in the design of pipeline systems. Only one type of valve was approved by the Navy that was considered to function satisfactorily. This valve for pipe-tank connections has been used for new construction and for replacement.

DOD - ARMY

Office, Chief of Engineers (OCE): **Eward C.Pritchett, Page Johnson, Dale Otterness**

The Army has some pipelines that they own and operate. Many of these pipelines are old. The Army also has some fuel storage tanks. There has not been reported damage to pipeline systems caused by earthquakes, however, one person interviewed thought that he had heard of some pipeline system damage attributed to earthquakes.

With regard to design criteria for pipeline systems, the Army uses Technical Manual TM 5-809-10-1,"Seismic Design Guidelines For Essential Buildings"; guide specifications for new construction of gas distribution systems and liquid fuel storage systems; and Navy Manual 22,"Petroleum Fuel Facilities". DOT regulations are generally followed although DOD is exempt for facilities on DOD property. None of these criteria address seismic provisions for transmission pipeline systems.

There has been some retrofit of pipeline systems, but not for reasons of seismic damage or to provide earthquake resistant design. Tanks and pipelines have been repaired and in some cases pipelines have been replaced. Each base has their own policy regarding retrofit and replacement procedures.

DOD - AIR FORCE

Ronald Wong, Sid McCard

The Air Force owns and operates liquid fuel pipeline systems located on their installations in the United States and in foreign countries. Some of the pipeline systems are old. The Air Force does not own, operate, lease, or regulate oil, fuel, or natural gas transmission pipeline systems.

Design criteria used by the Air Force for pipeline systems include DOT regulations, API requirements, ASME/ANSI requirements, and Army and Navy guide specs and design manuals. Guide specs for the design of bulk storage tanks are being updated. In general, design criteria do not address seismic provisions for earthquake resistant design for pipeline systems. Design considerations generally include environmental and safety requirements.

There have not been any known problems with Air Force owned or operated pipeline systems caused by earthquakes. Also, there are no plans for retrofitting these systems based on seismic considerations. There has been some repair of tanks because of leaks.

Recently designed (November 1990) aircraft fuel storage above-ground steel tanks for the Air Force were based on criteria for seismic zones 1 and 2. The specification stated that if the site specific design criteria exceed the general design criteria, structural elements shall be redesigned if necessary. Seismic investigation and redesign shall be in accordance with API 650 and TM 5-809-10/NAVFAC P-355/AFM 88-3,Chapter 13. The tanks were designed by a contractor by authority of the Corps of Engineers. Many Navy and Army guide specifications were used in the design of these fuel storage tanks. Specific provisions for earthquake resistant design were not given in the specification for the design of the steel tanks.

GENERAL SERVICES ADMINISTRATION (GSA)

Tom Graves, Bruce Hall

GSA is not involved with oil, fuel, or natural gas transmission pipeline systems, they are not in the business of moving fuel. With regard to GSA sites, distribution lines are the responsibility of the utility company. GSA is mostly concerned with buildings and with regard to seismic design provisions they have adopted the Uniform Building Code. They are also currently preparing additional seismic criteria for the design of their buildings.

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)

Davis White, Bob Fuller, Jerry Tobias

HUD is not involved with oil, fuel, or natural gas transmission pipeline systems, however they have some involvement with distribution pipeline systems, in particular with public housing. HUD generally provides the funds for these distribution systems and approves the design of the systems. Local codes, reference standards, and reference model building codes are used in the design of the distribution pipeline systems.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA: **Charlie Pittinger**
Ames Research Center, CA: **Bob Dolci, Mike Falarski**

NASA does not own, operate, lease, or regulate oil, fuel, or natural gas transmission pipeline systems. They do own and operate gas distribution lines at some facilities such as the Ames Research Center in California. Transmission pipelines are operated by utility companies. From these transmission pipelines, NASA takes oil and gas into the facility for internal use. The internal lines range in age from relatively new to the 1940's. The distribution or internal lines include some pipeline system components.

There have been minor problems at the Ames Research Center caused by earthquakes such as broken gas lines and leaks at connections and valves. In general, the piping systems performed satisfactorily. There was an earthquake in 1989 at the Ames Research Center.

Current design procedures which include national standards are used by NASA in the design and construction of pipeline systems. There has been little retrofit or replacement of pipelines. Retrofit for gas lines at the Ames Research Center has been by the use of plastic linings, and steel pipe has been replaced with plastic pipe. PGE uses plastic gas lines in their distribution systems.

Some emergency procedures have included backup generators for alternate fuel sources for generation of power and heat and for awhile there was available a backup propane system. Pipelines can be shut down or isolated in some cases by acceleration activated automatic valves and there are in use some manually operated valves.

TENNESSEE VALLEY AUTHORITY (TVA)

Jerry Cook, Don R. Denton

The TVA is not involved with oil, fuel, or natural gas transmission pipeline systems. They do have some distribution systems.

DEPARTMENT OF AGRICULTURE (DOA)

DOA: **Keith Surdiek, James R. Talbot**
Rural Electrification Administration: **Lee A. Belfore**

The Department does not own, operate, lease, or regulate oil, liquid fuel, or natural gas transmission pipeline systems. The only pipelines utilized are those for water and sewage systems, including those for irrigation. They are involved in the design of these systems.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

Thomas J. Moran

The EPA does not own, operate, lease, or regulate oil, liquid fuel, or natural gas transmission pipeline systems.

FEDERAL HIGHWAY ADMINISTRATION (FHWA)

James Cooper

The FHWA is not involved with oil, liquid fuel, or natural gas transmission pipeline systems.

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